Effect of thermal accumulation and spraying with salicylic acid on yield, its components and some physiological and qualitative indicators of sorghum (Sorghum bicolor L)

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Abstract

A field experiment was conducted in one of the fields of Ibn Al-Bitar vocational school in Al-Husseiniyah district in the Holy governorate of Kerbala for the spring season of 2023, with the aim of knowing the effect of planting dates and spraying with salicylic acid on some growth indicators and yield in Sorghum. The experiment was carried out according to a randomized complete block design (RCBD), in a split-plot arrangement, with three replications. The main plots included salicylic acid spray concentrations (0, 50, 100 and 150 ml L-1). While the sub plots included planting dates (March 1, March 10, and March 20). The results showed that the third date was superior in number of days from planting to physiological maturity (112.89 day), heat accumulation to physiological maturity (1883 thermal units), head length (30.28 cm), number of grains in the head (4938 grain head-1), grain yield (8.88 tons ha-1), protein percentage (9.78%) and proline percentage (5.70%). While the concentration exceeded 150 mg L-1 in number of days from planting to physiological maturity (112.89 day), head length (30.62 cm), number of grains in the head (4907 grain head-1), grain yield (8.26 ton ha-1), protein percentage (9.57%) and proline percentage in the leaves (7.20%.(

Keywords: Sorghum, Thermal accumulation, Salicylic acid, Qualitative indicators, Physiological indicators.

Introduction

Sorghum (Sorghum bicolor L.) is an important agricultural crop with multiple uses globally, as it contains a large amount of protein necessary for building tissues and muscles, and car-bohydrates that provide energy for the body, and contains important minerals such as iron, zinc, magnesium, and phosphorus that increase its nutritional value. It also has a crucial role in achieving food security, especially in develop-ing countries such as those in Africa. It is con-sidered an important staple crop as it provides sustenance for the population [1], it is also used in many food industries and is commonly used in the production of flour, pasta, bread and other food products in addition to that. The dried ones are used in the animal feed in-dustry. Moreover, it serves as a raw material for the production of starch, sugar and oils, which contributes to the food and beverage in-dustry on a larger scale [2 .[

Sorghum is considered one of the crops that is greatly affected by harsh weather conditions, including drought conditions, high

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temperatures, and fluctuations in rainfall levels, and thus it is exposed to environmental stress [3]. To deal with these harsh conditions and to improve the growth of sorghum and achieve a better crop, it is recommended to use techniques such as foliar spraying. Salicylic acid improves the tolerance of plants, including sorghum, to various envi-ronmental stresses, including drought, high tem-perature, salinity, and oxidative stress, meaning it serves as a signaling molecule that triggers a series of biochemical and physiological responses in plants and thus helps them withstand stress. It also acts as a major regulator of the plant defense system, especially the SAR (systemic acquired resistance) pathway, by activating the expression of genes involved in defensive responses such as the production of proteins and antioxidants associated with the pathogenesis of disease and thus helps protect the plant from biotic and abiotic stresses. It also stimulates root growth in Plants, that is, the development of enhanced roots encourages efficient nutrient and water absorption, allowing plants to better tolerate drought and other adverse conditions[4.[

One of the factors that can contribute to in-creasing crop productivity is planting in the ap-propriate season, meaning that planting Sorghum at the appropriate time corresponds to the local climate and the appropriate growing season. The correct timing helps ensure the availability of appropriate temperature and appropriate environmental conditions for the correct growth of the plant, and this reflects positively on the availability of degrees appropriate temperature and thermal balance contribute to stimulating strong, healthy root growth, which plays an important role in absorbing water and nutrients from the soil and helps enhance the plant's stability and resistance to environmental chal-lenges [5], Appropriate temperature also works to enhance the plant's vertical growth, which leads to an increase in the number of leaves and length. This means that there is more space for photosynthesis and the formation of more pro-ductive elements, such as dahlias in Sorghum. It also contributes to enhancing the processes of flowering, flower formation, and flower pollina-tion, which ultimately leads to an increase in production and the size of the harvest [6 .[

Materials and Methods

A field experiment was carried out during the spring season of 2023 in one of the fields be-longing to Ibn Al-Bitar vocational Preparatory school in Al-Husseiniyah district, Kerbala, Iraq. The experiment was carried out according to a randomized complete block design (RCBD), in a split-plot arrangement, with three replications, the main plots included salicylic acid spray con-centrations (0, 50, 100 and 150 ml L-1). While the sub plots included planting dates (March 1, March 10, and March 20). After plowing and leveling the field soil, sorghum seeds were planted (Bohuth70 cultivar approved by the Ira-qi Ministry of Agriculture), the seeds were planted in one hole and on a farrow, one the dis-tance (75 cm) and the distance between another hole (25 cm). Nitrogen fertilizer was added in the form of urea fertilizer in two batches, and phosphate fertilizer was added at planting, both according to the recommendations approved by the Iraqi Ministry of Agriculture. All agricultural operations were carried out during the crop growth period.

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Data recorded

The number of days from planting to physiologi-cal maturity (day). was calculated Thermal and cumulative collection of the number of days from planting to physiological maturity (heat unit). Some other traits were also calculated, such as head length (cm), number of grains in the head (grain head-1), grain yield (ton ha-1). As for the qualitative traits, the percentage of protein (%) and the percentage of proline in the leaves (%) were calculated. Note that the traits studied above were taken for five random plants from each experimental unit .

Statistical analysis

The results were statistically analyzed according to the analysis of variance (ANOVA) as per the ran-domized complete block design (R.C.B.D), the least significant difference (L.S.D0.05) test was used to compare and separate the means [7], this is done us-ing statistical analysis software GenStat12.

Results and discussion

Number of days from planting to physiological maturity (day(

The results of Table 1 showed that there were significant differences between the planting dates in terms of the number of days from planting to physiological maturity, as the third planting date excelled, giving an average of 107.60 day, compared to the first and second dates, which gave averages of 125.55 and 118.49 day, respectively. Perhaps the reason for the early rate of flowering occurs at the third planting date and completion of physio-logical maturity due to several factors, includ-ing the best growth conditions such as temper-ature, light, humidity, and rainfall in order to fully exploit the genetic potential of the crops. Perhaps the earlier date at the third date is due to the speed of physiological processes inside the plant cells due to high temperatures and the accumulation of a sufficient number of thermal units, necessary for the plant to reach the subsequent stages of growth, and this is affected by the photoperiod, which is necessary to reach full physiological maturity in a shorter time, and this is consistent with what he found [8.[

The results of Table 1 also showed that spray-ing with salicylic acid gave significant differ-ences in the number of days from planting to physiological maturity, as the concentration of 150 mg L-1 gave the best average of 112.89 day, compared to the control treatment, which gave an average of 120.31 day. Perhaps this is due to the early period, flowering reaches physiological maturity when sprayed with salicylic acid, due to its natural role in heat reactions and accumula-tion, stimulating flowering, and controlling the activity of stomata in the leaf through the differ-entiation of leaf cells through balancing the age of the photosynthetically active sites and pre-venting the loss of early flowering. These results are consistent with what he reached [9.[

The results of Table 1 also showed that there is no significant interaction between planting dates and spraying with salicylic acid in terms of the number of days from planting to physiological maturity of Sorghum

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Table 1: Effect of planting dates and spraying with salicylic acid and their interaction on the number of days from planting to physiological maturity (day).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	128.40	123.64	108.89	120.31
50 mg L^{-1}	125.01	122.20	108.64	118.62
100 mg L^{-1}	127.22	115.28	108.58	117.03
150 mg L^{-1}	121.55	112.84	104.28	112.89
Means	125.55	118.49	107.60	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	2.36	3.64	N.S	

Thermal and cumulative collection of the number of days from planting to physiologi-cal maturity

The data in Table 2 showed the superiority of the third date, which gave the lowest average for the cumulative thermal accumulation trait for the number of days from planting to physiologi-cal maturity, as it reached (1883 heat unit), compared to the comparison treatment, which gave the highest average for this trait, which reached (2380 heat unit), as it is considered the least thermal accumulation. It is ideal, as the plant needed fewer days to reach physiological maturity because the planting date was ideal and it excelled in the number of grains and grain yield, as it allowed the accumulation of dry mat-ter and reaching early flowering [10.[

As for the concentrations of spraying with salicylic acid, the concentration exceeded 150 mg L-1 in less thermal accumulation, which reached (2032 heat unit), while the comparison treatment gave the highest thermal accumula-tion, which reached (2235 heat unit). The ideal thermal accumulation that accumulates is less thermal accumulation to reach physiological maturity, due to spraying with salicylic acid, which works to early the flowering process due to its effect on plant growth factors, photosyn-thesis processes, and accumulation of dry mat-ter, and stimulates the plant to enter the flower-ing stage [11.[

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Table 2: Effect of planting dates and spraying with salicylic acid and their interaction on the thermal accumulation trait of the number of days from planting to physiological maturity (heat unit).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	2445	2334	1927	2235
50 mg L^{-1}	2365	2294	1915	2191
100 mg L^{-1}	2439	2099	1898	2189
150 mg L^{-1}	2273	2031	1792	2032
Means	2380	2189	1883	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	65.50	101.40	N.S	

Head length (cm(

The results of Table 3 showed that there were significant differences between the planting dates in the head length trait, as the third date gave the highest average of 30.28 cm, while the first and second dates gave 27.55 and 29.12 cm, respectively. The increase in the third period is due to the efficiency of thermal collection, which achieved a thermal accumulation of 1883 thermal units (Table 2), which may have affected the improvement of the growth of the daughters by improving photosynthesis, enhancing growth activity, and accumulating dry matter, and thus increasing the length of the head [12.[

The results of Table 3 showed that spraying with salicylic acid achieved a significant increase in head length, as the concentration of 150 mg L-1 gave the highest average of 30.62 cm, compared to the control treatment, which gave the lowest average of 27.74 cm. Perhaps the increase in head length when spraying with salicylic acid is attributed to its role In improving plant growth and increasing the efficiency of the photosynthesis process, as this acid plays a physiological role in increasing plant efficiency by improving plant growth and increasing the accumulation of dry matter that leads to increasing head length [13.[

The results of Table 3 also showed that there is no significant interaction between planting dates and spraying with salicylic acid in head length trait.

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Table 3: Effect of planting dates, spraying with salicylic acid and their interaction on head length (cm).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	25.93	27.62	29.68	27.74
50 mg L^{-1}	25.71	28.35	30.26	28.11
100 mg L^{-1}	28.66	29.63	30.09	29.46
150 mg L^{-1}	29.91	30.87	31.08	30.62
Means	27.56	29.09	30.28	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	1.57	1.05	N.S	

Grains number (grain head-1(

The results in Table 4 indicate that there are significant differences between the planting dates in terms of the number of grains per head. The third date gave the highest average of 4938 grain head-1, compared to the first and second dates, which gave averages of 3881 and 4460 grain head-1, respectively. The supe-riority of the third date is attributed to giving The highest average number of grains per head indicates that this date obtained an ideal ther-mal collection amounting to (1883) thermal units (Table 2) through increasing the efficien-cy of the photosynthesis process and increas-ing the accumulation of dry matter in the grains, which reduced the rate of miscarriage in the ovaries and the occurrence of this signif-icant increase. In the number of grains per head, these results are consistent with the re-sults of [14], who found a significant effect of planting dates on the number of grains per head of sorghum crop.

The results of Table 4 showed that spraying with salicylic acid caused a significant increase in the number of grains in the head, as the concentration of 150 mg L-1 gave the highest average of 4907 grain head-1, compared to the control treatment, which gave an average of 3902 grain head-1. Perhaps the increase in the number of grains in the head is attributed to its role in regulating many From physiological processes, including the process of photo-synthesis, which increased the efficiency of dry matter formation in the reproductive stag-es, and this was reflected in one of the most important components of the yield [15,16.[

The results of Table 4 also showed a signif-icant interaction between planting dates and spraying with salicylic acid in the number of grains per head. The concentration of 150 mg L-1 at the third planting date gave the highest average of 5476 grain head-1. While the con-centration of 50 mg L-1 at the first planting date gave the lowest average of 3598 grain head-1.

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Table 4: Effect of planting dates and spraying with salicylic acid and their interaction on the number of grains per head (grain head^{-1}).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	3868	3801	4038	3902
50 mg L^{-1}	3598	4113	5130	4280
100 mg L^{-1}	3824	4915	5108	4616
150 mg L^{-1}	4234	5011	5476	4907
Means	3881	4460	4938	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	351.20	188.22	395.50	

Grain yield (ton ha-1(

The results of Table 5 showed that there were significant differences between the planting dates in grain yield trait, and that the third date excelled by giving the highest average of 8.88 ton ha-1, compared to the first and second dates, which gave averages of 6.42 and 7.91 ton ha-1, respectively. This may be due to the increase Grain yield at the third planting date indicates the plant's ability to accumulate sufficient pho-tosynthetic products and intercept the greatest amount of sunlight in the vegetative growth stage, which was reflected in an increase in the yield per plant [17]. Or the reason may be that the increase in grain yield increases with the in-crease of one or more of its components (Table 4) that this third date was significantly higher in the number of grains per head, which reflected positively on the increase in grain productivity. These results agreed with [18,19], who found a significant difference between the planting dates of the Sorghum crop high in grain yield.

The results of Table 5 showed that spraying with salicylic acid caused a significant increase in the grain yield trait, as the concentration of 150 mg L-1 gave the highest average of 8.26 ton ha-1, compared to the control treatment that gave the lowest average of 6.93 ton ha-1. Perhaps the reason for the increase in grain yield trait is at-tributed to At a concentration of 150 mg L-1 with salicylic acid, the physiological effect of this acid in accelerating the processes of trans-ferring nutrients to grains, and this increased their yield, and this study agrees with [20.[

The results of Table 5 also showed that there is no significant interaction between planting dates and spraying with salicylic acid in grain yield trait.

Table 5: Effect of planting dates, spraying with salicylic acid and their interaction on grain yield (ton ha^{-1}).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	5.43	7.13	8.23	6.93
50 mg L^{-1}	6.58	8.10	8.80	7.83
100 mg L^{-1}	6.66	7.86	9.27	7.93
150 mg L^{-1}	7.00	8.57	9.21	8.26
Means	6.42	7.91	8.88	
L.S.D$_{0.05}$	Planting dates	Concentrations	Interaction	
	1.35	3.86	N.S	

Proline concentration (mg L-1(

The results of Table 6 showed that there were significant differences between planting dates in the concentration of proline in the leaves, as the first date gave the highest average of 7.24 mg L-1, compared to the second and third dates, which gave averages of 6.55 and 5.70 mg L-1, respectively. Perhaps the reason for the increase in proline concentration at the first date is due to the physiologi-cal mechanism, to protect plant cells from abiotic stresses, the most important of which is high and low temperatures, is to increase the concentration of amino acids with protective properties, includ-ing proline acid, which has an effective role in protecting the plant [21.[

The results of Table 6 showed that spraying with salicylic acid caused a significant increase in the concentration of proline in the leaves, as the concentration of 150 mg L-1 gave the highest average of 7.20 mg L-1, compared to the control treatment, which gave the lowest average of 5.63 mg L-1. The results of Table 5 showed that spraying with salicylic acid caused a significant increase in the proline concentration in the leaves, as the concentration of 150 mg L-1 gave the highest average of 7.20 compared to the control treatment, which gave the lowest average of 5.63 mg L-1 .The reason for the increase in proline concentration when sprayed with salicylic acid may be attributed to the activity of amino acid synthesis enzymes that work to protect plant cells from premature damage. It may be a means of defense against abiotic stresses and enhances the activities of antioxidant enzymes. The most important of them are peroxidase, ethylene, polyphenol, and phenylalanine, which are among the basic plant defense hormones, and the increase in proline, which works in preserving the pigments in the leaf, as it is a non-enzymatic antioxidant compound that works to prevent active oxygenation [22,23 .[

The results of Table 6 also showed that there is no significant interaction between planting dates and spraying with salicylic acid in the concentration of proline in the leaves trait.

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Table 6: Effect of planting dates, spraying with salicylic acid and their interaction on the concentration of proline in the leaves (mg L^{-1}).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	6.40	5.52	4.99	5.63
50 mg L^{-1}	6.91	6.07	5.41	6.13
100 mg L^{-1}	7.49	7.92	5.69	7.03
150 mg L^{-1}	8.18	6.71	6.70	7.20
Means	7.24	6.55	5.70	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	1.093	0.625	N.S	

Protein%

The results of Table 7 showed that there were significant differences between planting dates in the percentage of protein in grains, as the third date had the highest average of 9.78%, compared to the first and second dates, which gave averages of 7.64% and 8.94%, respectively. Environmental conditions have a significant impact on the quality of Sorghum grains, as the degree of Daily temperature has a major role in improving protein and starch accumulation, as [24] confirmed that the late planting date reduced the nitrogen content of the seed, and this greatly affected the protein content in the grain. The high protein content at the third date is due to suitable growth conditions. Temperature, light and humidity required during the growth period .[25 [

The results of Table 7 showed that spraying with salicylic acid caused a significant increase in the character of the protein percentage, as the concentration of 150 mg L-1 gave the highest percentage of 9.57%, compared to the control treatment that gave the lowest percentage of 7.96%. This may be the reason for the increase in the protein percentage in the grains. It is linked to high concentrations of salicylate and the positive role in improving and raising the efficiency of major elements, the most important of which is nitrogen, which accelerates its transfer to grains and then this is reflected in increasing the percent-age of protein [26.[

The results of Table 7 also showed that there is no significant interaction between planting dates and spraying with salicylic acid in the percentage of protein in grains.

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Table 7: Effect of planting dates, spraying with salicylic acid and their interaction on protein percentage (%).

Concentrations	Planting dates			Means
	First date	Second date	Third date	
0 mg L^{-1}	6.10	8.85	8.93	7.96
50 mg L^{-1}	7.19	8.59	9.46	8.42
100 mg L^{-1}	8.70	9.04	9.90	9.21
150 mg L^{-1}	8.56	9.25	10.84	9.57
Means	7.64	8.94	9.78	
$L.S.D_{0.05}$	Planting dates	Concentrations	Interaction	
	1.438	1.154	N.S	

Conclusion

We conclude from the above that different planting dates had an important role in increasing some quantitative and qualitative indicators, based on the compatibility of the nature of environmental factors at a specific date (The third date) with the nature of the growth of the Sorghum crop. Spraying with salicylic acid (150 mg L-1) also played a clear role in increasing or improving the plant's efficiency in exploiting the available food resources, which contributed to increasing some of the quantitative and qualitative traits of the Sorghum plant.

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